JC10 Rec'd PCT/PTO 18 DEC 2001

FORM PTO-1390 (REV. 11-2000) | US DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER **P/63035-PCT**

U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 10/018759

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/IB00/00809	**June 8, 2000**	**June 19, 1999**

TITLE OF INVENTION **Phase Error Detector for a Quadrature Amplitude Modulated (QAM) Receiver**

APPLICANT(S) FOR DO/EO/US **Gerhard HERBIG**

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. [X] This is an express request to begin national examination procedures (35 U.S.C. 371 (f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. [ ] The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   - a. [ ] is attached hereto (required only if not communicated by the International Bureau).
   - b. [X] has been communicated by the International Bureau.
   - c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [X] An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   - a. [X] is attached hereto.
   - b. [ ] has been previously submitted under 35 U.S.C. 154(d)(4).
7. [X] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
   - a. [ ] are attached hereto (required only if not communicated by the International Bureau).
   - b. [ ] have been communicated by the International Bureau.
   - c. [X] have not been made; however, the time limit for making such amendments has NOT expired.
   - d. [ ] have not been made and will not be made.
8. [ ] An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. [ ] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. [X] An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [ ] A FIRST preliminary amendment.
14. [ ] A SECOND or SUBSEQUENT preliminary amendment.
15. [ ] A substitute specification.
16. [ ] A change of power of attorney and/or address letter.
17. [ ] A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
18. [ ] A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. [ ] A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. [X] Other items or information: **Receipt Acknowledgment Postcard**

10/018759 531 Rec'd PCT... 18 DEC 2001

U.S. APPLICATION NO. (if known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO PCT/IB00/00809	ATTORNEY'S DOCKET NUMBER P/63035-PCT

21. [X] The following fees are submitted:

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

	CALCULATIONS	PTO USE ONLY
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO $1,040.00		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO $890.00		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO $740.00		
International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) $710.00		
International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) $100.00		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$890.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).	$0.00	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	$	
Total claims	3 - 20 =	0	x **$18.00**	$0.00	
Independent claims	1 - 3 =	0	x **$84.00**	$0.00	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			**+ $280.00**	$0.00	
TOTAL OF ABOVE CALCULATIONS =				$890.00	
[ ] Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				$0.00	
SUBTOTAL =				$890.00	
Processing fee of **$130.00** for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				$0.00	
TOTAL NATIONAL FEE =				$890.00	
Fee for recording the enclosed assignment (37 CFR 1.21 (h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +				$0.00	
TOTAL FEES ENCLOSED =				$890.00	
				Amount to be refunded:	$
				charged:	$

a. [X] A check in the amount of <u>**$890.00**</u> to cover the above fees is enclosed.

b. [ ] Please charge my Deposit Account No. ________________ in the amount of $__________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [X] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 11-1145. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

KIRSCHSTEIN, OTTINGER, ISRAEL & SCHIFFMILLER, P.C.
489 Fifth Avenue
New York, New York 10017
(212) 697-3750

SIGNATURE: [signature]

Alan Israel
NAME
27,564
REGISTRATION NUMBER

I hereby certify that this correspondence is being deposited with the U.S. Postal Service as Express Mail No. EL 337 911 785 US in an envelope addressed to: Box: PCT, Commissioner of Patents and Trademarks, Washington, D.C., 20231, on:
December 18, 2001
(date) ***Alan Israel*** ***Reg. No. 27,564***

Phase Error Detector for a QAM Receiver

Prior Art

The present invention concerns a phase error detector for a QAM receiver in which all QAM signal states that are present are stored and each of the QAM signal states lying in a complex signal state plane is surrounded by a decision region and the phase error detector detects, by threshold value decisions, in which decision region of a QAM signal state a complex received signal state broken down into its in-phase and quadrature-phase signal components falls and it forms a phase correction signal for the carrier phase of the received signal as a function of the detected decision region. Such a phase error detector is known from DE 36 19 744 A1.

Standard phase error detectors for QAM (quadrature-amplitude modulated) signals, which are also the point of departure in DE 36 19 744 A1, possess, in addition to the reference lock-in point at a phase error of $\varphi = 0$, additional undesired zeros in their phase characteristics, which can lead to lengthened synchronization times and to synchronization in unsuitable phases. For example, phase characteristics of such standard phase error detectors are shown in Figure 4 for 16-QAM, 32-QAM, 64-QAM and 120-QAM, which have several undesired zeros, in addition to the one at the lock-in point $\varphi = 0$. An algorithm for a phase error detector is described in DE 36 19 744 A1, whose phase characteristic no longer has the interfering zeros. However, the method described in DE 36 19 744 A1 has properties that have proven disadvantageous in practical systems. The slope of the static phase characteristic is an important dimensioning parameter for the phase control loop of carrier recovery in a QAM receiver. The slope of the static phase characteristic at the lock-in point in the known method is heavily dependent on the signal-to-noise ratio of the received signal: it is small at a poor signal-to-noise ratio and tends toward infinity at a good signal-to-noise ratio. This strong variation of slope of the phase characteristic makes good dimensioning possible only with significant compromises. Moreover, all other standard phase error detectors based on the sign operations of the decision error, also possess this property.

Moreover, the static phase characteristics formed by known phase error detectors only make a statement concerning the average behavior of a phase error detector. During locking-in of a phase

control loop, i.e., on transition from the lock-in phase to the followup phase, the average behavior does not play much of a role, but a uniformly good contribution of all QAM signal states does.

The underlying task of the invention is to offer a phase error detector of the type just mentioned that generates a phase correction signal in such a way that its phase characteristic has no undesired zeros.

Advantages of the Invention

The mentioned task is solved with the features of Claim 1, in that several algorithms are available to the phase error detector for calculation of the phase correction signal. Which of the available algorithms is chosen for calculation of the phase correction signal depends on the decision region of the complex QAM signal state plane into which a received signal state broken down into its in-phase and its quadrature phase signal component falls. Five different algorithms for calculation of the phase correction signal are given in Claim 1. Owing to the fact that the phase correction signal is not calculated according to the same algorithm for all decision regions, as in the prior art, but different algorithms are available, a phase characteristic can be implemented that no longer has undesired zeros, on the one hand, and guarantees uniform contribution of all QAM signal states, on the other hand. Which algorithm is the most suitable for which decision region can be determined empirically.

Advantageous modifications of the invention according to Claim 1 are apparent from the subclaims.

Drawing

The invention is further explained below with reference to a practical example depicted in the drawing. In the drawing:

Figure 1 shows a block diagram of a QAM receiver,

Figure 2 shows a complex QAM signal state plane,

Figure 3 shows several phase characteristics of phase detectors designed according to the invention and

Figure 4 shows several phase characteristics of standard phase error detectors.

Translated by:
TCA–Translation Co. of America
10 West 37th Street
New York, N.Y. 10018
(212) 563-7054

09857045 .032602

Description of a Practical Example

A block circuit diagram of a QAM receiver is shown in Figure 1. The QAM receiver consists of an in-phase signal branch and a quadrature-phase signal branch. A mixer MI is situated in the in-phase signal branch and a mixer MQ in the quadrature-phase signal branch. These two mixers MI and MQ convert the received signal ES, which is divided on both signal branches, into the base band. The reference frequency for the two mixers MI and MQ is delivered by a voltage-controlled oscillator VCO. The reference frequency signal generated by this voltage-controlled oscillator is fed from one of the two mixers to a 90° phase shifter PS, so that the reference frequencies of the two mixers MI and MQ have a mutual phase offset of 90°. The output signal of mixer MI, which represents the in-phase signal component ZI of a received signal state, and the output signal of mixer MQ, which represents the quadrature-phase signal component ZQ of a received signal state, are fed to a phase error detector PFD. This phase error detector PFD, as described in detail below, generates a phase correction signal S that serves as control signal for the voltage-controlled oscillator VCO.

The following equations will clarify how the phase error detector determines, from the individual received signal state with the in-phase signal component ZI and the quadrature-phase signal component ZQ, the phase correction signal S that represents the offset of the carrier phase of the received signal relative to the phase of the reference frequency signal generated by the voltage-controlled oscillator VCO. The phase error detector PFD calculates the phase correction signal S according to a widely known method according to equation (1).

$$S = FQ\,ZI - FI\,ZQ \qquad (1)$$

FI and FQ are the decision errors, which, as expressed in equation (2), are the offsets of the in-phase signal component ZI and the quadrature-phase signal component ZQ of the received signal state relative to the in-phase component AI and the quadrature-phase component AQ of the QAM signal state for which the phase error detector PFD decided that this is the transmitted signal state emitted by a transmitter.

$$FI = ZI - AI$$
$$FQ = ZQ - AQ \qquad (2)$$

Translated by:
TCA–Translation Co. of America
10 West 37th Street
New York, N.Y. 10018 (212) 563-7054

During transmission of the transmitted signal state without distortion, the received signal state $Z = ZI + jZQ$ is only rotated by an angle φ relative to the transmitted signal state $A = AI + jAQ$. This is expressed by equation (3).

$$Z = Ae^{j\varphi} - (AI + jAQ)(\cos\varphi + j\sin\varphi) \qquad (3)$$

The function shown in equation (1) is not often used to calculate the phase correction signal, but rather the sign version according to equation (4), which requires no demanding multiplication.

$$S = FQ\ \mathrm{sign}(ZI) - FI\ \mathrm{sign}(ZA) \qquad (4)$$

The static phase characteristic is the average of all possible QAM transmitted signal states, as shown in equation (5).

$$S(\varphi) = E(FQ\ \mathrm{sign}(Zf) - FI\ \mathrm{sign}(ZQ)) \qquad (5)$$

Because of equation (2), the following applies to the quadrature component of the decision error:

$$FI = AI\cos\varphi - AO\sin\varphi - AI$$
$$FO = AQ\cos\varphi - AI\sin\varphi - AO \qquad (6)$$

With (6), the following applies for the phase correction signal S according to (1).

$$S = (AQ\cos\varphi + AI\sin\varphi - AQ)(AI\cos\varphi - AQ\sin\varphi) -$$
$$(AI\cos\varphi \cdot AQ\sin\varphi - AI)(AQ\cos\varphi + AI\sin\varphi) \qquad (7)$$

With this phase correction signal with $E(A^2) = 1$, a static phase characteristic line is obtained according to equation (8).

$$S(\varphi) = -\cos\varphi\sin\varphi + \sin\varphi\cos\varphi - \sin\varphi - \cos\varphi\sin\varphi - \sin\varphi\cos\varphi - \sin\varphi = 2\sin\varphi \qquad (8)$$

This calculation of the static phase characteristic, however, presumes validity of equation (2), i.e., an error-free coordination of the received signal state to the transmitted signal state. For QAM signal constellations, this means a restricted validity range dependent on the modulation method of the phase characteristic according to equation (8), for example [-45°, +45°] for 4-QAM, [-16.5°, +16.5°] for 16-QAM, etc.

Phase characteristics according to the sign version according to equation (4) do not have a sinusoidal trend in the validity region, but a linear trend. Phase characteristics for 16-QAM, 32-QAM, 64-QAM and 128-QAM receivers are shown in Figure 4, which calculate the phase

Translated by:
TCA–Translation Co. of America
10 West 37th Street
New York, N.Y. 10018
(212) 563-7054

correction signal in the standard method according to equation (5). In all four modulation methods, undesired zeros, i.e., false lock-in points, are present; they are most clearly apparent in 32-QAM. In this modulation method, the longest residence times in the undesired phase positions are also found.

In order to avoid undesired zero transitions in the phase characteristic, five different calculation methods for the phase correction signal are available to the phase error detector:

$$\begin{aligned} S1 &= FQ\ f(ZI) - FI\ f(ZQ) \\ S2 &= \pm 2\ FQ\ f(ZI) \\ S3 &= \pm 2\ FI\ f(ZQ) \qquad (9) \\ S4 &= \pm 2\ ZI\ ZQ \\ S5 &= 0 \end{aligned}$$

In the four calculation methods S1 to S4, the following applies for the functions f(ZI) and f(ZQ):

$$f(ZI) = ZI \text{ and } f(ZQ) = ZQ$$

or

$$f(ZI) = \mathrm{sign}(ZI) \text{ and } f(ZQ) = \mathrm{sign}(ZQ)$$

Which one the five calculation methods S1 to S5 is used for the phase correction signal of the phase error detector depends on the decision region of a QAM signal state in which a complex received signal state broken down into its in-phase signal component ZI and its quadrature-phase signal component ZQ falls.

In allocating the calculation methods S1 to S5 to the individual decision regions, the fractions of all transmitted symbols are considered individually on the static phase characteristic. Thus, for example, there are precisely 16 different transmission symbols A(i), i = 1 ... 16 and therefore 16 fractions S(i) in 16-QAM modulation, which on average then form the static phase characteristic S:

$$S = \frac{1}{16}\sum_{(0)}^{16} S(i) \qquad (10)$$

In order to obtain a favorable trend for the phase characteristic S, the transmission symbols A(i) that possess a negative range $S(i) < 0$ for positive angles $\varphi > 0$ or a positive range for a negative value are identified in the first step. In this case, the method S1, i.e., the standard method, is initially

presumed for all decision regions. These regions then lead in equation (10) to the undesired zeros in the overall behavior of the phase correction characteristic S. In the second step, the decision regions that yield the undesired correction information in the corresponding transmission symbol A(i) are then determined. In the third step, it can be tested whether one of the methods S2 or S3 brings a desired improvement. After processing of all transmission symbols and all decision regions, an improvement of the trend of the phase characteristic is generally established. However, it can happen that the improvement is still not sufficient. For the remaining regions $S(i) < 0$ for $\varphi > 0$, or $S(i) > 0$ for $\varphi < 0$, the methods S4 and S5 are then used, but in which only as many decision regions are chosen until the desired zeros have reliably disappeared in the phase characteristics. Methods S4 and S5 are therefore used with restraint, because they cause a deformation (although a slight one) of the static phase characteristic at the lock-in point. The method described here is expediently performed with computer support, but in which some decisions must be made empirically.

The complex signal state plane of a 16-QAM system is shown in Figure 2 as an example. The indices I of the in-phase signal component run from 0 to 4 on the abscissa of the coordinate system of the complex QAM signal state plane and the indices Q of the quadrature-phase signal components also run from 0 to 4 on the ordinate of the coordinate system. The 16 square points in the signal state plane correspond to the 16 QAM transmitted signal states, and the three thin concentric circles on which the square points lie are the tracks of the received signal states with deficient carrier phase synchronization. The squares that enclose the signal states (square points) are referred to as decision regions. The phase error detector PFD determines, by threshold value decision, in which decision region of a certain QAM signal state a complex received signal state broken down into its in-phase signal component ZI and its quadrature-signal component ZQ falls. The direction and strength of the phase correction information calculated by the phase error detector are shown by the color (black, white) and size of the circles drawn in Figure 2. Black circles produce a phase correction in the positive direction (counterclockwise) and white circles in the negative direction (clockwise). Large circles correspond to a strong correction, small circles to a weak correction. In the eight fields marked 0, no correction information at all is generated (corresponds to method S5).

The thickly bordered decision regions in Figure 2 experience a modification relative to the known standardized phase error detection. Different calculation methods according to equation (9)

Translated by:
TCA–Translation Co. of America
10 West 37th Street
New York, N.Y. 10018 (212) 563-7054

are used for them for the phase correction signal. The indices I and Q, which describe the position of the decision region, are shown in the following table in the section 16-QAM. In addition, for each decision region, i.e., for each combination I/Q, the calculation method selected from the five calculation methods S1 to S5 is performed. For example, for the decision regions 0/3 and 3/0, the value 0 is required there, which corresponds to method S5. In regions 0/4, 1/4, 4/0 and 4/1, the correction information is constant; this correspond to calculation method S4. In the two decision regions 1/3 and 3/1, the phase correction information is only dependent on a decision error FI or FQ, which is expressed in Figure 2 by orientation of the point size parallel to the axis; calculation methods S2 and S3 come into play here.

Why the choice just described of different calculation methods S1 to S5 leads to an improvement for the phase correction signal of static phase characteristics with undesired zeros can be explained as follows:

The four outer decision regions 0/4, 1/4, 4/0 and 4/1 are clearly in the phase correction information. It therefore makes sense to choose for these cases the maximum value established by the control region. However, not all decision regions whose correction information is clear may be treated in this manner, because the trend of the static phase characteristic should to be distorted as little as possible in the vicinity of the origin (finite slope of the phase characteristic at the lock-in point $\varphi = 0$). For this reason, for example, the regions 0/1 and 1/0 are unchanged.

The regions 0/3 and 3/0 yield false correction information for the specific phases, because a high uncertainty exists on the average circle with reference to the actually transmitted signal state. Filtering out these decision regions is essential and accordingly these regions are marked with a zero in Figure 2 for which calculation method S5 is considered.

The two regions 1/3 and 3/1 are encountered either in the lock-in phase of a rotating corner point or in the follow-up of an adjacent noise-affected received signal state. In the first case, these decision regions furnish correct phase correction information and in the second case, insignificant information. In order for these decision regions to yield the highest possible phase correction information in the first case and the least possible phase correction information in the second case, only one quadrature component FI or FQ of the decision error is evaluated according to the calculation method S2 or S3.

Translated by:
TCA–Translation Co. of America
10 West 37th Street
New York, N.Y. 10018 (212) 563-7054

The following tables can also give the decision regions for the individual calculation methods S1 to S5 for 32-QAM, 64-QAM and 128-QAM systems.

16-QAM

Index I	Index Q	Method
3	0	S5
0	3	S5
3	1	S3
1	3	S2
4	0	S4
0	4	S4
4	1	S4
1	4	S4
All others	All others	S1

32-QAM

Index I	Index Q	Method
3	0	S5
0	3	S5
4	0	S3
0	4	S2
4	2	S3
2	4	S2
5	1	S3
1	5	S2
5	2	S4
2	5	S4
All others	All others	S1

Translated by:
TCA–Translation Co. of America
10 West 37th Street
New York, N.Y. 10018
(212) 563-7054

64-QAM

Index I	Index Q	Method
3	0	S5
0	3	S5
4	0	S3
0	4	S2
4	2	S3
2	4	S2
5	1	S3
1	5	S2
5	2	S4
2	5	S4
7	3	S3
3	7	S2
8	2, 3, 4, 5	S4
2, 3, 4, 5	8	S4
9	0, 1, 2, 3, 4	S4
0, 1, 2, 3, 4	9	S4
All others	All others	S1

Translated by:
TCA–Translation Co. of America
10 West 37th Street
New York, N.Y. 10018

(212) 563-7054

TCA Translation

128-QAM

Index I	Index Q	Method
3	0	S5
0	3	S5
4	0	S3
0	4	S2
4	2	S3
2	4	S2
5	1	S3
1	5	S4
5	2	S4
2	5	S4
7	3	S3
3	7	S2
8	5	S5
5	8	S5
9	3	S3
3	9	S2
9	7	S5
7	9	S5
9	8	S5
8	9	S5
10	2	S5
2	10	S5
10	7	S5
7	10	S5
10	8	S5
8	10	S5
11	5	S3
5	11	S2
11	6	S4
6	11	S4
12	3	S4
3	12	S4
12	4	S4
4	12	S4
All others	All others	1

With the depicted allocations of the different calculation methods S1 to S5 for the phase correction signal, we obtain for the 6-QAM, 32-QAM, 64-QAM and 128-QAM systems the phase characteristics shown in Figure 3, which have an unaltered trend at the lock-in point $\varphi = 0$ and no undesired zeros.

Translated by:
TCA–Translation Co. of America
10 West 37th Street
New York, N.Y. 10018

(212) 563-7054

Claims

1. Phase error detector for a QAM receiver in which all QAM signal states present are stored and each of the QAM signal states lying in a complex signal state plane is enclosed by a decision region and the phase error detector, by threshold value decisions, detects in which decision region of a certain QAM signal state a complex received signal state broken down into its in-phase (ZI) and its quadrature-phase signal component (ZQ) falls and forms as a function of the detected decision region a phase correction signal (S) for the carrier phase of the received signal (ES), characterized by the fact that

- the phase error detector (PFD) calculates the phase correction signal (S) according to the detected decision region according to one of the following methods:

$S1 = FQ\ f(ZI) - FI\ f(ZQ)$

$S2 = \pm 2\ FQ\ f(ZI)$

$S3 = \pm 2\ FI\ f(ZQ)$

$S4 = \pm 2\ ZI\ ZQ$

$S5 = 0$

in which ZI and ZQ are the in-phase and quadrature-phase signal components of the received signal states and FI and FQ the offsets of ZI and ZQ relative to the in-phase and quadrature-phase components of the decided QAM signal state,

- and that the phase error detector (PFD) causes a coordination to the decision regions and the individual calculation methods (S1 to S5), so that its static phase characteristic exhibits no additional zeros, except at the lock-in point in which the phase offset between the reference carrier of the receiver and the received signal carrier is zero.

2. Phase error detector according to Claim 1, characterized by the fact that the following applies for the calculation methods (S1 to S3): f(ZI) = ZI and f(ZQ) = ZQ.

3. Phase error detector according to Claim 1, characterized by the fact that the following applies for the calculation methods (S1 to S5): f(ZI) = sign(ZI) and f(ZQ) = sign(ZQ).

Translated by:
TCA–Translation Co. of America
10 West 37th Street
New York, N.Y. 10018 (212) 563-7054

14087545.022802

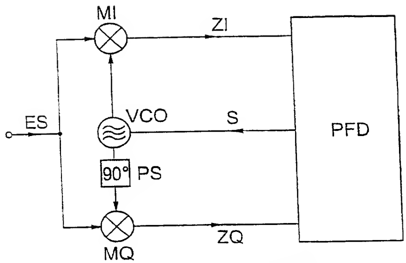

FIG. 1

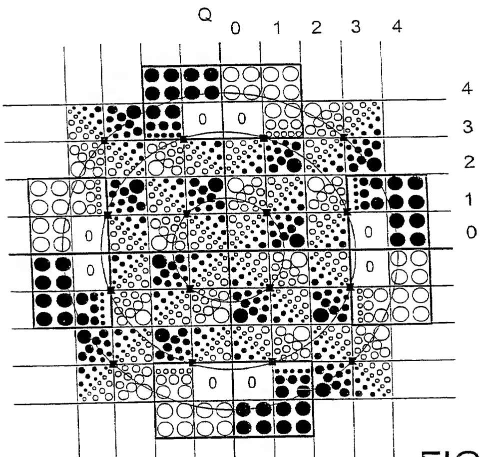

FIG. 2

2/3

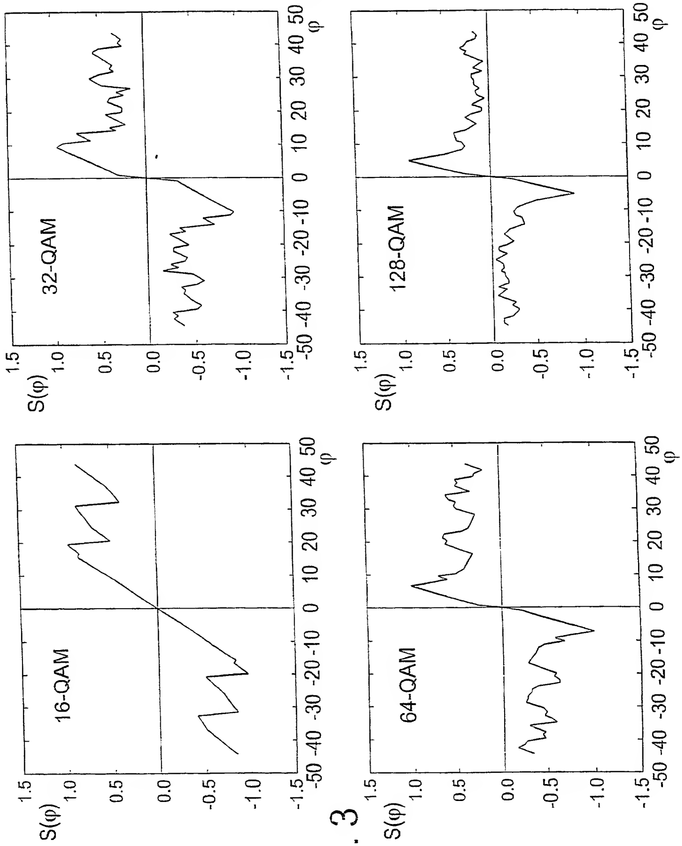
16-QAM
32-QAM
64-QAM
128-QAM
S(φ)
φ
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-50 -40 -30 -20 -10 0 10 20 30 40 50

FIG. 3

10/018759

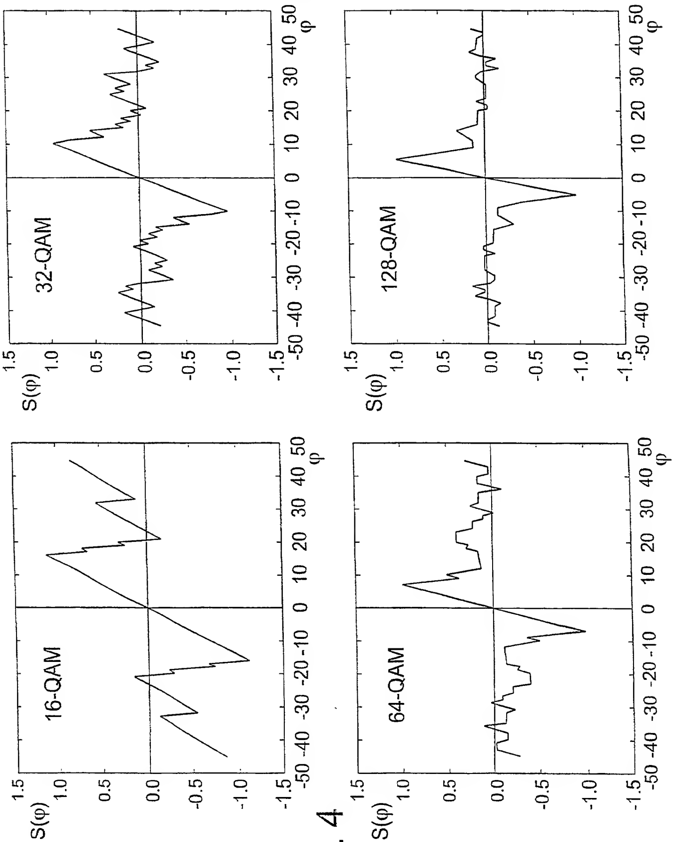

FIG. 4

Type a plus sign (+) inside this box → +

PTO/SB/01 (6-95)
Approved for use through 9/30/98 OMB 0651-0032
Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

0010/PTO
Rev. 6/95

U.S. Department of Commerce
Patent and Trademark Office

DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION

☐ Declaration Submitted with Initial Filing OR ☒ Declaration Submitted after Initial Filing

Attorney Docket Number	P/63035
First Named Inventor	HERBIG, GERHARD
COMPLETE IF KNOWN	
Application Number	10/018,759
Filing Date	DECEMBER 18, 2001
Group Art Unit	
Examiner Name	

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled :

PHASE ERROR DETECTOR FOR A QUADRATURE AMPLITUDE MODULATED (QAM) RECEIVER

(Title of the Invention)

the specification of which

☐ is attached hereto

OR

☒ was filed on (MM/DD/YYYY) DECEMBER 18, 2001 as United States Application Number or PCT International

Application Number 10/018,759 and was amended on (MM/DD/YYYY) ______ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37 Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code §119 (a)-(d) or §365(b) of any foreign application(s) for patent or inventor's certificate, or §365 (a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	NO
19928206.4	Germany	06.19.99 June 19 1999	☐	☐	☒
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐
PCT/IB00/00809	INTERNATIONAL	06.08.2002 JUNE 8, 2002	☐	☐	☒

☐ Additional foreign application numbers are listed on a supplemental priority sheet attached hereto:

I hereby claim the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)	☐ Additional provisional application numbers are listed on a supplemental priority sheet attached hereto.

Burden Hour Statement: This form is estimated to take .4 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231.

Type a plus sign (+) inside this box → [+]

+

DECLARATION

I hereby claim the benefit under Title 35, United States Code §120 of any United States application(s), or §365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code §112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. Parent Application Number	PCT Parent Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number *(if applicable)*

☐ Additional U.S. or PCT international application numbers are listed on a supplemental priority sheet attached hereto.

As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

☐ Firm Name ______ Customer Number or label ______
OR
☒ List attorney(s) and/or agent(s) name and registration number below:

Name	Registration Number	Name	Registration Number
David B. Kirschstein, Esq.	17,244		
Alan Israel, Esq.	27,564		
Martin W. Schiffmiller, Esq.	30,421		

3

☐ Additional attorney(s) and/or agent(s) named on a supplemental sheet attached hereto.

Please direct all correspondence to: ☐ Customer Number or label ______ OR ☒ Fill in correspondence address below

Name	KIRSCHSTEIN, OTTINGER, ISRAEL & SCHIFFMILLER, P.C.				
Address	489 Fifth Avenue				
Address					
City	New York	State	New York	ZIP	10017-6105
Country	United States	Telephone	(212) 697-3750	Fax	(212) 949-1690

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name of Sole or First Inventor: ☐ A petition has been filed for this unsigned inventor

1-00

Given Name	Gerhard	Middle Initial		Family Name	HERBIG	Suffix e.g. Jr.	
Inventor's Signature	X Gerhard P. Herbig				Date	X 21.12.01	
Residence: City	Oppenweiler DEX	State		Country	Germany	Citizenship	German
Post Office Address	Reutenhofstrasse 42/2, D-71570 Oppenweiler, Germany.						
Post Office Address							
City	Oppenweiler	State		Zip	D-71570	Country	Germany
Applicant Authority							

☐ Additional inventors are being named on supplemental sheet(s) attached hereto